Chapter 10: Fresh Concrete – Curing Methods

Introduction

Concrete gains its strength and durability through the process of hydration, where water reacts with the cement to form a hard matrix. However, hydration is a time-dependent and moisture-dependent process. For hydration to proceed effectively and for concrete to achieve its designed strength, it must be maintained in a moist condition for a certain period after placing and finishing. This process is known as **curing**.

Curing not only affects strength development but also influences durability, volume stability, resistance to freezing and thawing, and abrasion resistance. Improper or insufficient curing can lead to surface cracks, dusting, and reduced life span of the concrete structure. In this chapter, we explore the methods of curing in detail, their mechanisms, advantages, limitations, and suitability for different situations.

10.1 Objectives of Curing

The main objectives of curing are:

1. **To maintain adequate moisture content** in the concrete to enable complete hydration of cement.
2. **To control the temperature** of concrete during the early hardening period, especially in hot and cold weather.
3. **To prevent shrinkage** and thermal cracks that result from rapid drying or temperature variations.
4. **To improve the overall performance** of concrete, including strength, impermeability, and durability.

10.2 Factors Affecting Curing

1. **Environmental conditions** – temperature, wind, humidity, and sunlight all influence evaporation rates.
2. **Type of cement** – faster-setting cements require more attentive early curing.
3. **Water-cement ratio** – low water-cement ratio mixes are more prone to rapid drying.
4. **Size and shape of the structure** – thin sections dry out quicker than massive ones.

5. **Placement method** – sprayed or pumped concrete may require different curing approaches.

10.3 Curing Methods

Curing methods can be broadly classified into **moist curing**, **membrane curing**, **application of heat**, and **miscellaneous methods**.

10.3.1 Water Curing (Moist Curing)

This is the most effective and widely used method of curing.

Types of Water Curing:

1. **Ponding**:
   - Water is retained on flat surfaces like slabs using temporary bunds.
   - Provides continuous water supply.
   - Suitable for horizontal surfaces.
   - **Advantage**: Uniform hydration, effective temperature control.
   - **Limitation**: Not suitable for vertical or inclined surfaces.
2. **Spraying or Fogging**:
   - Water is sprayed or fogged over the concrete surface using nozzles.
   - Suitable for vertical or irregular surfaces.
   - **Advantage**: Easy to apply, economical.
   - **Limitation**: Less effective in windy conditions.
3. **Wet Coverings**:
   - Hessian cloths, burlap, cotton mats, or straw are kept continuously wet and laid over the concrete.
   - **Advantage**: Suitable for complex shapes.
   - **Limitation**: Requires frequent wetting and supervision.
4. **Running Water**:
   - Used in large-scale concrete works like canal linings, dams, and bridge decks.
   - Continuous flow ensures constant moisture.
   - **Limitation**: Needs a large water supply.

10.3.2 Membrane Curing

When water is not easily available or continuous water curing is not feasible, **membrane-forming compounds** are used.

Types of Membrane Curing:

1. **Liquid Membrane-Forming Compounds (LMFCs)**:
    - These are sprayed or rolled on the concrete surface.
    - They form a thin film that reduces moisture loss.
    - Materials used include chlorinated rubber, acrylics, wax emulsions, and bituminous compounds.
    - **White pigmented membranes** are used to reflect sunlight and reduce surface temperature.
2. **Plastic Sheets**:
    - Polyethylene or PVC sheets are laid over the concrete surface.
    - The edges are sealed to prevent air ingress.
    - **Advantage**: Economical, suitable for small works.
    - **Limitation**: Risk of wind blowing the sheet away, surface discoloration.
3. **Impervious Paper**:
    - Bitumen-coated paper can be used for covering.
    - Usually not as effective as liquid membranes or plastic sheets.

10.3.3 Steam Curing

Used primarily in **precast concrete** production where fast strength gain is required.

Types:

1. **Atmospheric Pressure Steam Curing**:
    - Steam is applied at ambient pressure, typically within curing chambers.
    - Temperature: 60–80°C.
    - **Used for**: Precast blocks, pipes, panels.
2. **High-Pressure Steam Curing (Autoclaving)**:
    - Conducted in autoclaves under pressure (8–12 atm) and high temperature (150–180°C).
    - Speeds up strength gain considerably.
    - Converts calcium hydroxide into stable calcium silicate hydrates (C-S-H).

- **Used for**: Aerated concrete products (e.g., AAC blocks).

Advantages:

- Rapid early strength.
- Early removal from molds.
- Higher production rates.

Limitations:

- Expensive setup.
- Not suitable for site concreting.

10.3.4 Infrared Radiation and Electrical Heating

Used in cold climates or where conventional methods are not practical.

- **Infrared lamps** or **electric resistance wires** are installed near or around the concrete.
- Used for **floorings**, **bridge decks**, or **cold weather concreting**.
- Requires monitoring to avoid overheating or thermal cracks.

10.3.5 Curing Compounds with Internal Curing Agents

An advanced method using **specially treated lightweight aggregates** or **superabsorbent polymers (SAPs)** that retain moisture within the concrete.

- These materials release moisture slowly during hydration.
- Helps in **low water-cement ratio concrete**, **high-performance concrete (HPC)**, and **self-compacting concrete (SCC)**.

10.4 Duration of Curing

The minimum duration depends on environmental conditions and type of cement:

Cement Type	Minimum Curing Period
Ordinary Portland	7 days
Blended Cement (PPC, PSC)	10 days
In hot/dry climates	10–14 days
Steam curing	12–24 hours post placement (followed by air curing)

For important works, curing is often continued up to 14–28 days.

10.5 Effects of Inadequate Curing

- **Reduction in strength** by up to 40%.
- **Surface shrinkage cracks** due to rapid drying.
- **Loss of durability** due to permeability and poor hydration.
- **Dusting and scaling** of surfaces.
- **Increased risk of corrosion** of reinforcement due to low cover strength.

10.6 Selection of Curing Method

Condition	Recommended Method
Hot, dry climate	Water curing + white pigmented LMFC
Water-scarce regions	Membrane curing or internal curing
Cold weather	Steam or electrical curing
Precast concrete	Steam curing
Massive pours	Water curing (ponding or spraying)
Decorative concrete	Wet coverings or curing sheets

10.7 IS Code Provisions for Curing

As per **IS 456:2000 – Plain and Reinforced Concrete – Code of Practice**:

- Concrete must be **cured for a minimum of 7 days** in normal conditions.
- When blended cement is used, **not less than 10 days**.
- In **dry and hot weather**, the curing period shall be **extended to 14 days**.
- Use of **curing compounds** is permitted provided they are approved and tested for effectiveness.

10.8 Modern Innovations in Curing Techniques

10.8.1 Self-Curing Concrete (Internal Curing)

Self-curing or **autogenous curing** is achieved using materials embedded within the concrete matrix that retain water and release it slowly during hydration.

Materials Used:

- **Pre-soaked lightweight aggregates** (e.g., expanded shale or clay).
- **Super Absorbent Polymers (SAPs)** – capable of absorbing and later releasing 100–500 times their weight in water.

- **Hydrogels** – synthetic polymer materials engineered to provide moisture over an extended period.

Benefits:

- Eliminates the need for external water curing.
- Ideal for high-performance concrete with low w/c ratios.
- Reduces early-age shrinkage and thermal cracking.
- Enhances microstructure and durability.

10.8.2 Smart Sensors and IoT in Curing

The use of **wireless sensors** and **embedded IoT devices** allows real-time monitoring of:

- Internal temperature
- Humidity levels
- Strength gain (using maturity index correlation)
- Moisture evaporation rate

Advantages:

- Real-time data improves decision-making (e.g., formwork removal, post-tensioning).
- Alerts on improper curing or temperature spikes.
- Integration with BIM (Building Information Modelling) systems for quality assurance.

10.9 Curing in Special Conditions

10.9.1 Cold Weather Curing

In temperatures below **5°C**, the rate of hydration drops drastically. If water freezes before hydration, it leads to internal cracking and permanent damage.

Precautions:

- Use heated enclosures or insulated blankets.
- Use accelerators (e.g., calcium nitrate) and low w/c ratio mixes.
- Delay placement until minimum temperature is reached.
- Avoid rapid thawing.

10.9.2 Hot Weather Curing

High temperatures (>35°C), low humidity, and strong winds accelerate water evaporation from the surface before hydration is complete.

Preventive Measures:

- Use chilled mixing water or ice flakes.
- Start curing **immediately** after final set.
- Use white-pigmented curing compounds to reflect heat.
- Shade the concrete from direct sunlight.
- Limit concrete temperature to <32°C at the time of placement (IS 7861 Part I).

10.10 Case Studies and Failures due to Improper Curing

10.10.1 Case Study: Bridge Deck Cracking (U.S.)

- A major highway bridge experienced **longitudinal cracking** within 28 days of casting.
- Investigation revealed curing was stopped after 3 days due to labor unavailability.
- Strength tests showed 25% lower compressive strength at 56 days.
- **Lesson**: Minimum 7–14 days curing must be strictly enforced regardless of visible set.

10.10.2 Case Study: Residential Slab Dusting (India)

- Ground floor slab developed **surface dusting and flaking** within months.
- Site used only plastic sheets for 2 days, with no spraying afterward.
- Petrographic analysis showed incomplete cement hydration in top 10 mm layer.
- **Remedial action**: Slab topping was removed and replaced with proper curing (7 days of ponding).

10.11 Quality Control and Inspection of Curing

10.11.1 Inspection Checklist

Parameter	Method	Frequency
Moisture retention	Visual + touch test	Daily

Parameter	Method	Frequency
Temperature (in mass pours)	Embedded thermocouples	Hourly (critical phase)
Curing compound application	Thickness test with micrometer	Per surface area
Duration of curing	Logbook and timer	Daily update
Surface cracking/shrinkage	Visual with grid measurement	3-day intervals

---

10.11.2 Testing for Effectiveness of Curing

1. **Compressive Strength Testing** (IS 516):
   - Compare samples cured as per standard and field conditions.
2. **Moisture Retention Test** (ASTM C156):
   - Measures how well a curing compound prevents evaporation.
3. **Maturity Method** (ASTM C1074):
   - Combines time and temperature to estimate strength gain.
4. **Ultrasonic Pulse Velocity (UPV)** (IS 13311 Part 1):
   - Non-destructive test to check uniformity of curing.

10.12 Environmental and Economic Aspects

10.12.1 Water Usage Concerns

- Water curing can consume **10–30 liters per square meter** over 14 days.
- For large-scale projects, this becomes environmentally and economically critical.

Solutions:

- Use **recycled water** for curing (if free of harmful salts).
- **Rainwater harvesting** for curing operations.
- **Membrane compounds** for low-water zones.

10.12.2 Cost Comparison

Method	Initial Cost	Labour	Water Use	Durability Impact
Water curing (ponding)	Low	High	High	Excellent
LMFC (curing compounds)	Medium	Low	Low	Good
Steam curing	High	Medium	Low	Good
Self-curing agents	High	Low	None	Excellent